[1] **Shahad Ahmed Abd-Alameer**

[2]**Ibrahim Ramadhan Agool**

[3]**Ali Sadam Lefta**

[4]**Nadir Fadhil Habubi**

[5]**Hiba Saad Rasheed**

[6]**Sami Salman Chiad**

Preparation and Characterization of Nanostructured Manganese-Doped Zinc Oxide Thin Films

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Abstract: - By spray pyrolysis (SP) process, thin films of ZnO and (ZnO:Mn) with 1% and 3% concentrations were created at a temperature of 400 °C. According to XRD investigation, ZnO films are polycrystalline and have a cubic structure with a distinct peak in one direction (101). The grain size increases as manganese content rise, from 12.66 nm to 14.66 nm. While the strain () for ZnO reduced after manganese doping, it decreased from 27.36 to 23.63. Surface topography and nanostructure study reveal that as the manganese (Mn) content of ZnO films increased, cluster grain size, average roughness, and root mean square roughness (Rrms) all significantly reduced. The average transmittance was >70% in the visible area for Undoped ZnO and 1, 3% Manganese doping optical transmittance demonstrates exceptional optical transparency. When doping levels are increased by 1% or 3%, the absorption coefficient rises.The optical band gap was decreased from (3.32 to 3.21) eV. Results illustrate that the films' refractive index and extinction coefficient decreases with increasing Tin Doped.

Keywords: ZnO, Mn, XRD, topography, transmittance, absorption coefficient, band gap.

I. INTRODUCTION

Zinc oxide has many applicationsdu to its excellent optical, photoelectric, and piezoelectric properties. Thus, this approach is ideal for realizing optical devices, including LED, and solar cells. In the applications above, zinc oxide (ZnO) with a hexagonal wurzite structure has recently shown potential as an ITO alternative [1-4]. It is particularly interested in wide bandgap semiconductors due to the growing commercial need for short-wavelength LED [5-8]. ZnO-nanostructured films are a great option because of their wide bandgap (3.37 eV) [8, 9]. ZnO is grown using a variety of techniques, such CVD [10, 11], sol–gel [12–14], magnetron sputtering [15, 16], laser molecular beam epitaxy [17] and as spray pyrolysis (SP) [18–24], Spray pyrolysis is one of these techniques suitable for broad-area thin film production and simple doping. We report the experimental findings of physical attributes discovered using various characterization methods in this paper. The thin films is grown via SP technique. The temperature and deposition time are crucial because this is a chemical procedure. The Manganese

[1] *College of Education for Women University of Thi-Qar Thi-Qar, Iraq*
shahad.ahmad@utq.edu.iq

[2]Bilad Alrafidain University College, *Diyala, Iraq*
dr.agool@bauc14.edu.iq

[3]*dept. Physics College of Education, Mustansiriyah University Baghdad, Iraq*
alisadam@uomustansiriyah.edu.iq

[4]*dept. Engineering of Refrigeration and Air Conditioning Technologies Alnukhba University College Baghdad, Iraq*

n.fadhil@alnukhba.edu.iq

[5]*dept. Physics College of Education, Mustansiriyah University Baghdad, Iraq*
hibasaad@uomustansiriyah.edu.iq

[6]*dept. Physics College of Education, Mustansiriyah University Baghdad, Iraq*
dr.sami@uomustansiriyah.edu.iq

Doping significantly impacts the deposited Undoped ZnO thin films. Manganese doping has been used to develop several thin films while maintaining stable substrate temperatures

II. EXPERIMENTAL

The current study used CSP to manufacture Mn-doped ZnO film on a glass slide substrate. Thin films of ZnO were produced using this technique. 0.1 M of $ZnCl_2$ dissolved in the 1:1 mixture of deionized water and ethanol was used to manufacture ZnO thin films. The doping substance was manganese trichloride (MnCl3), which was dissolved in deionized water and then had a few drops of hydrochloric acid added to it so the solution would be transparent. The following are the requirements for preparation: Base temperature was 400 ^oC, there was a distance of 28 cm between spout and the substrate, and the spraying period was 8 S , but it was prolonged by 65 seconds to prevent cooling, the spray rate was 5 ml/min. and N_2 was employed as the transporter gas. The thickness was determined using the gravimetric method of 340 ± 20 nm. ZnO thin film generated was established by XRD, and AFM was used to evaluate the films' structure and morphology. Transmittance is estimated using a UV-Vis NIR.

III. RESULTS AND DISCUSSIONS

Figure (1) displays the XRD patterns of ZnO thin film created using a straightforward chemical method before annealing. This figure has several peaks at angles of 31.73°, 36.24°, 47.42°, and 62.65° that are attributed to the (100), (101), (102), and (103) planes, respectively. These peaks could be fitted by ICDD card number (36.1451) [25, 26], showing the presence of polycrystallanity and predominant peak in (101) plane [27, 28].

The grain size (D) was calculated using Scherrer's Eq. (1) [29-31]:

$$D = \frac{0.9\lambda}{\beta cos\theta} \qquad (1)$$

Where λ is the X-rays' wavelength, β and θ are FWHM and the Bragg angle of (101) peak, respectively. Table 1 displays the outcomes that were attained. The findings demonstrate that *D* rises from 12.66 to 14.66 nm when the ZnO content is increased to ZnO: 3% Mn. As a result, the manganese content is crucial in adjusting the crystal sizes of the material [32, 33].

Evaluation is also done on other structural metrics, including dislocation density (δ) from Eq. 1[34-36].

$$\delta = \frac{1}{D^2} \qquad (2)$$

The calculation of the strain (ε) is calculated via Eq. 2 [37-39]:

$$\varepsilon = \frac{\beta cos\theta}{4} \qquad (3)$$

Table 1 displays the data, and it is clear that the strain declines as the manganese content rises. The regular atom arrangements in the crystal lattice are responsible for improving crystalline quality [15]. We can infer from these findings that the manganese concentration fundamentally impacts crystallite size and decreases from 12.66 to 14.66 [40,41]. Figure (2), shows the structural parameters S_{para} as functions of Manganese concentration.

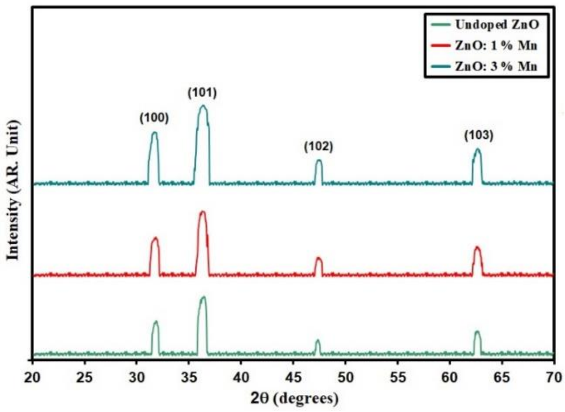

Fig.1. XRD patterns.

TABLE 1. D, Eg and $_{Spara}$ of prepared films.

Samples	2 q (º)	(hkl) Plane	β (º)	E_g (eV)	D (nm)	(δ) (× 10^{14}) (lines/m^2)	(ε) (× 10^{-4})
Undoped ZnO	36.24	101	0.66	3.32	12.66	62.33	27.36
ZnO: 1% Mn	36.21	101	0.62	3.26	13.48	54.97	25.7
ZnO: 3% Mn	36.17	101	0.57	3.21	14.66	46.47	23.63

The three-dimensional surface morphology is depicted in Fig. 3. Table 2 displays the produced films' average particle size P_{av}, root mean square roughness (Rrms), and average roughness (Ra). ZnO, ZnO:1% Mn, and ZnO:3% Mn nanoparticles were found to have average particle sizes in the range of (92.6), (85.7), and (47.8) nm, respectively. When doping was reduced, the Rrms value is dropped to 1.99 nm [42, 43]. Ra values are shown in Figs. 3(a3), (b3), and (c3), respectively. The AFM parameter P_{AFM} values are shown in Table (2).

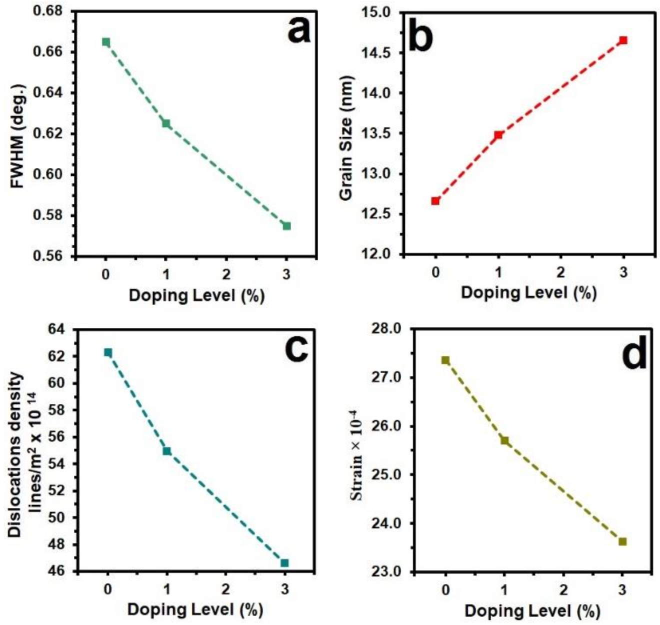

Fig.2. S_{Para} of the grown films.

TABLE 2. P_{AFM} of the intended films.

Samples	P_{av} nm	R_a (nm)	R_{rms} (nm)
Undoped ZnO	92..6	8.31	10.81
ZnO: 1% Mn	85.7	6.27	6.15
ZnO: 3% Mn	47.8	3.96	5.23

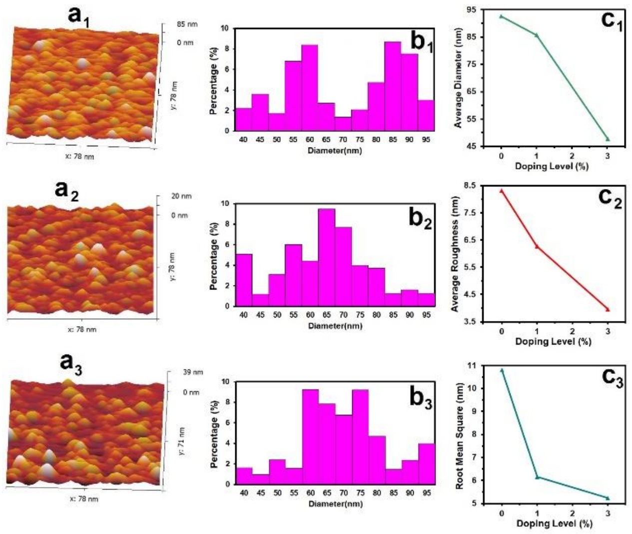

Fig. 3. AFM information's.

Fig. (4) offers the transmittance (T) spectra of ZnO film and doped films. The transmittance of ZnO film decreases by manganese content [44, 45].

The absorption coefficient (α) is determined [46-48]:

$$\alpha = \frac{2.303A}{t} \quad (4)$$

Where t is the film thickness, Fig. 5 depicts α increases with ncrease of manganese doping [49, 50].

The energy gap E_g is plotted following Tauc relation [51-53]:

$$(\alpha h\nu) = A\left(h\nu - E_g\right)^{\frac{1}{2}} \quad (5)$$

Where A is the constant, ν is the incoming radiation's frequency, and h is Planck's constant; Figure 4 shows the energy gap values were 3.32 and 3.21 eV, respectively. This graph demonstrates how the energy gap value of manganese-doped ZnO film is decreasing. These ideals align well with those expressed by other employees [54, 55].

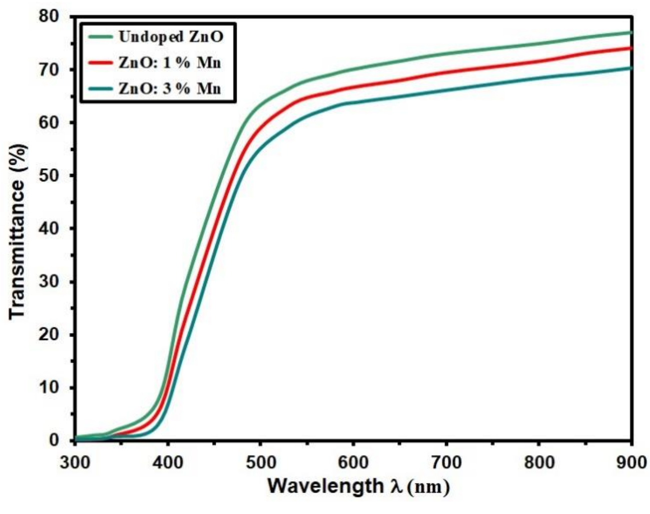

Fig. 4 T versus wavelength of the grown films.

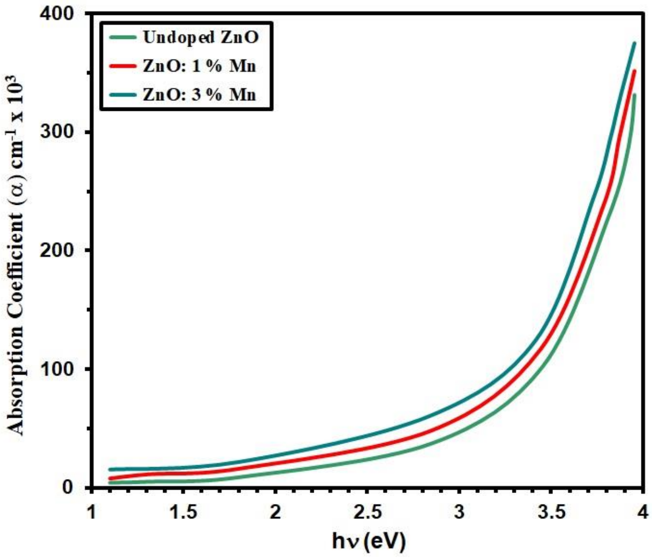

Fig. 5 α versus hν for deposited films.

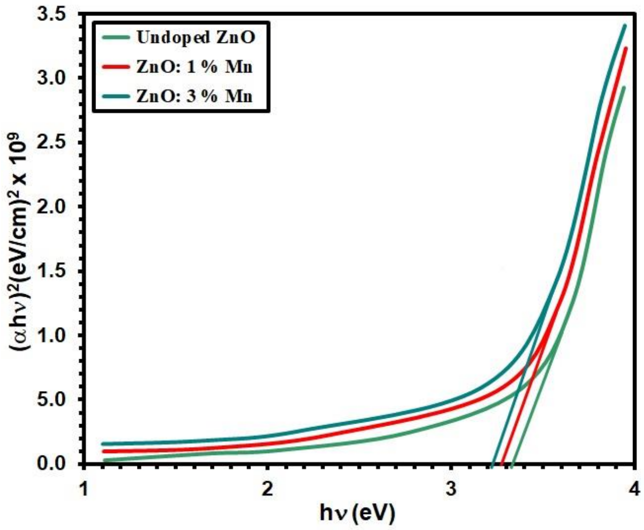

Fig. 6 E_g of the grown films.

The extinction coefficient (K) is meaured by Eq. 6 [56-58]:

$$k = \frac{\alpha\lambda}{4\pi} \qquad (7)$$

The variation of k is seen in Fig. 7. After magnesium doping, there is a modest drop in k, which is related to the wavelength of polarized light. k immediately recaptures its characteristic of absorption [59,60]. The refractive index n is obtained by Eq. (7) [61-63]:

$$n = \left(\frac{1+R}{1-R}\right) + \sqrt{\frac{4R}{(1-R)^2} - k^2} \qquad (8)$$

Where R is the reflectance, Fig. 8. displays n spectr against λ. There is a slight decrease in refractive index via Mn content [64, 65].

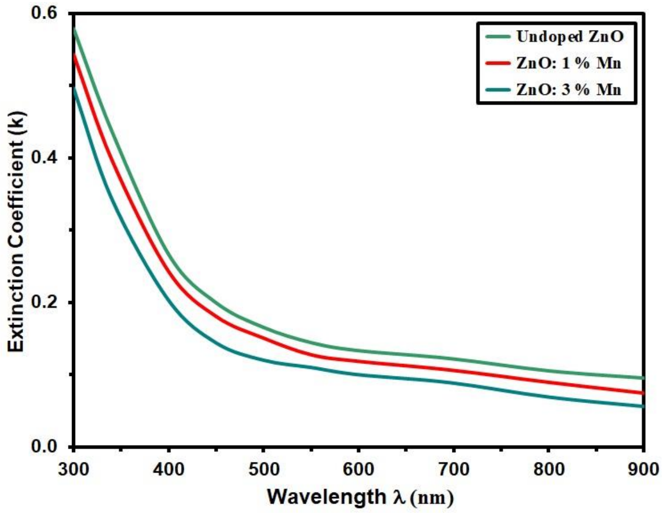

Fig. 7 k of the grown films.

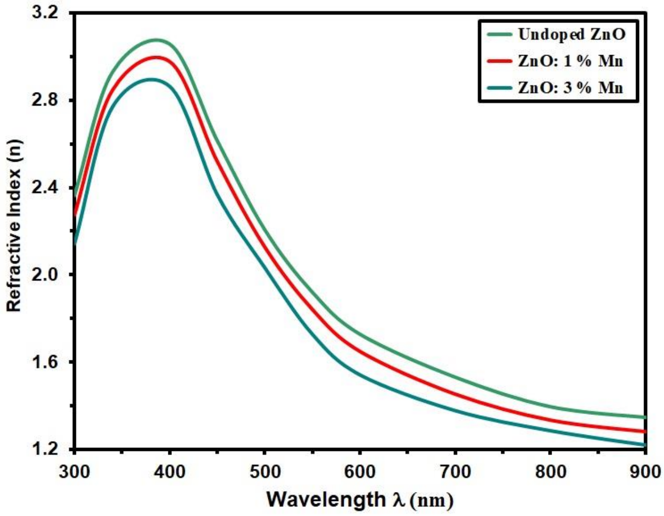

Fig. 8 n for grown films.

IV. CONCLUSION

We looked at spray pyrolysis-deposited thin films of zinc oxide. According to XRD findings, annealed ZnO films have a preferred orientation of 101 degrees. For prepared samples, microstructural parameters have been computed. Particle size increases as the manganese content does, from 12.66 nm to 14.66 nm. Undoped ZnO, ZnO:1% Mn, and ZnO:3% Mn nanoparticles were found to have grains between 92.6, 85.7, and 47.8 nm in size, respectively. The transmittance in the visible range is greater than 78 %. The absorption coefficient decreased by increase of Mn content and the bandgap values decreased from 3.32 to 3.21 eV with increasing of Manganese doped zinc oxide. Extinction coefficient and refractive index are lowered with manganese concentration.

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REFERENCES

[1] F. N. Sayed, K. F. Khaled, E. M. El-Menyawy, “Physical properties of Mn-doped ZnO thin films synthesized by spray pyrolysis technique”, Applied Physics A 125(11) (2019): 733.

[2] D.-H. Lee, K.-H. Park, S. Kim, S. Y. Lee, “Effect of Ag doping on the performance of ZnO thin film transistor”, *Thin Solid Films* 520 (2011): 1160–1164.

[3] O. Lupan, S. Shishiyanu, V. Ursaki, H. Khallaf, L. Chow, T. Shishiyanu, and V. Sontea, “Synthesis of nanostructured Al-doped zinc oxide films on Si for solar cells applications”, *Sol. Energy Mater. Sol. Cells,* 93 (2009): 1417–1422.

[4] X. D. T. Gao, X. M. Li, and W. D. Yu, “Structural and morphological evolution of ZnO cluster film prepared by the ultrasonic irradiation assisted solution route”, *Thin Solid Films* 484 (2005): 160–164.

[5] H. U. Khan, M. N. Malik, and M. Imran, “Structural and Optical Properties of Manganese-Doped Zinc Oxide Thin Films Prepared by Chemical Spray Pyrolysis”, Journal of Materials Science: Materials in Electronics 28 (9) (2017): 6344-6350.

[6] K. M. El-Shaer, M. M. Hafiz, H. A. Alghamdi, H. M. Zaki, “Manganese-doped zinc oxide thin films for gas sensing applications”, Journal of Nanomaterials, (2018): 1-7.

[7] K. M. El-Shaer, S. S. Ibrahim, and S. A. Ebrahim, “Manganese-Doped Zinc Oxide Thin Films for Gas Sensing Applications”, Journal of Nanomaterials, 2015 (2015): 1-10.

[8] M. A. Elsayed, E. A. Saadeldin, H. M. N. El-Deen, H. A. Moustafa, “Synthesis, structural and optical characterization of Mn-doped ZnO thin films prepared by sol-gel method”, Optical Materials 97 (2019): 109413.

[9] H. U. Khan, S. AlFaify, R. Jilani, A. S. Al-Dwayyan, M. S. Al-Salhi, “Structural and optical properties of manganese-doped zinc oxide thin films prepared by chemical spray pyrolysis” Journal of Materials Science: Materials in Electronics 26 (3) (2015): 1798-1803.

[10] M. A. R. Mendoza, D. O. Casanova, “Role of Ammonia on the Growth Mechanism of ZnO Films Deposited at Ambient Temperature”, ECS J. Solid State Sci. Technol. 9 (2020): 103002.

[11] K.D.A. Kumar, S. Valanarasu, S. R. Rosario, V. Ganesh, M. Shkir, C. Sreelatha, S. AlFaify, “Evaluation of the structural, optical and electrical properties of AZO thin films prepared by chemical bath deposition for optoelectronics”, Solid State Sci. 78 (2018): 58–68.

[12] S. S. Bellad, N. S. Sushma, and R. B. Basavaraj, “Synthesis and characterization of Mn-doped ZnO thin films using a sol-gel method”, Journal of Materials Science: Materials in Electronics 27 (7) (2016): 7156-7160.

[13] N. S. Sushma, S. S. Bellad, “Synthesis and Characterization of Manganese-Doped Zinc Oxide Thin Films by Sol-Gel Method”, Materials Today: Proceedings 5(2) (2018): 4255-4260.

[14] R. G. Mendes, L. F. Zagonel, and C. A. Achete, “Manganese-doped zinc oxide thin films deposited by sol-gel process: Synthesis and characterization”, Journal of Sol-Gel Science and Technology 61 (1) (2012): 107-115.

[15] J. Shi, L. Yang, Y. Chen, Y. Sun, “Electrical and magnetic properties of manganese-doped zinc oxide thin films prepared by RF magnetron sputtering”, Journal of Applied Physics 113(5) (2013): 053907.

[16] J. Shi, X. Xu, Y. Sun. “Electrical and Magnetic Properties of Manganese-Doped Zinc Oxide Thin Films Prepared by RF Magnetron Sputtering”, Journal of Applied Physics 105 (7) (2009): 07E142-07E142-3.

[17] X.-A. Zhang, J.-W. Zhang, W.-F. Zhang, D. Wang, Z. Bi, X.-M. Bian, X. Hou, “Enhancement-mode thin film transistor with nitrogen-doped ZnO channel layer deposited by laser molecular beam epitaxy”, Thin Solid Films 516 (2008): 3305–3308.

[18] R. Anitha, G. Vijayaprasath, D. Mangalaraj, “Effect of manganese doping on the structural and optical properties of ZnO thin films by spray pyrolysis technique”, Journal of Alloys and Compounds 665 (2016): 347-355.

[19] E.S. Hassan, T. H. Mubarak, K. H. Abass, S. S. Chiad, N. F. Habubi, M. H. Rahid, A. A. Khadayeir, M. O Dawod, I.A., Al-Baidhany, “Structural, Morphological and Optical Characterization of Tin Doped Zinc Oxide Thin Film by (SPT), Journal of Physics: Conference Series 1234(1) (2019): 012013.

[20] R. S. Ali, K. S. Sharba, A. M. Jabbar, Chiad, S. S., K. H. Abass, N. F. Habubi, “Characterization of ZnO thin film/p-Si fabricated by vacuum evaporation method for solar cell applications, NeuroQuantology 18(1) (2020): 26-31.

[21] A. Ghazai, K. Qader, N. F. Habubi , S. S. Chiad, O. Abdulmunem, “Structural and optical performance of the doped ZnO Nano-thin films by (CSP)”, IOP Conference Series: Materials Science and Engineering 870 (1) 2020.

[22] R. Narayanan, V. P. M. Pillai, “Characterization of manganese doped zinc oxide thin films prepared by spray pyrolysis”, Journal of Optoelectronics and Advanced Materials 17(9-10) (2015): 1346-1350.

[23] T. S. Tripathi, A. K. Singh, “Synthesis and characterization of Mn-doped ZnO thin films by spray pyrolysis technique”, Journal of Materials Science: Materials in Electronics 27(1) (2016): 572-577.

[24] Y. Gao, Y. Zhang, Y. Guo, Y. Zhang, “Structural and optical properties of Mn-doped ZnO thin films prepared by spray pyrolysis method” Journal of Materials Science: Materials in Electronics 29(18) (2018): 15462-15469.

[25] A. A. Ansari, S. G., Ansari M. H. Cho, H. M. Kim, J. Y. Lee, “Structural, optical and magnetic properties of Mn-doped ZnO thin films by spray pyrolysis”, Materials Science in Semiconductor Processing 25 (2014): 65-70.

[26] M. S. Rana, R. Sultana, M. Begum, M. A. Hossain, “Influence of Mn doping on structural and optical properties of ZnO thin films prepared by spray pyrolysis”, Journal of Electronic Materials, 48(5) (2019): 3018-3025.

[27] Z. Ali, J. Kim, “Influence of annealing temperature on the structural, optical and electrical properties of manganese-doped zinc oxide thin films synthesized by spray pyrolysis”, Applied Surface Science 481(2019): 1019-1025.

[28] A. Hussain, S. Ahmed, Mahmood, K. “Structural and optical characterization of Mn-doped ZnO thin films synthesized by spray pyrolysis technique”, Applied Physics A 120 (2) (2015): 491-497.

[29] N. N. Jandow, M. S. Othman, N. F. Habubi, S. S. Chiad, K. Mishjil, I. Al-Baidhany, “Theoretical and experimental investigation of structural and optical properties of lithium doped cadmium oxide thin films”, Materials Research Express 6 (11): (2020).

[30] A. A. Khadayeir, E. S. Hassan, T. H. Mubarak, S. S. Chiad, N. F. Habubi, M. O. Dawood, Al- I. A. Baidhany, “The effect of substrate temperature on the physical properties of copper oxide films”, Journal of Physics: Conference Series 1294 (2) (2019): 022009.

[31] E. H. Hadi, D. A. Sabur, S. S. Chiad, N. F. Habubi, K. H. Abass, “Physical properties of nanostructured li-doped zro_2 thin films, Journal of Green Engineering 10 (10) (2020): 8390-8400.

[32] R. C. Meena, H. C. Swart, R. E. Kroon, Structural, morphological, and optical properties of manganese-doped zinc oxide thin films prepared by spray pyrolysis”, Applied Physics A 122 (10) (2016): 1-7.

[33] Y. Zheng, X. Zhang, J. Wang, X. Han, “Influence of Mn doping on structural and optical properties of ZnO thin films fabricated by chemical spray pyrolysis” Journal of Materials Science: Materials in Electronics 30(6) (2019): 5716-5722.

[34] A. J. Ghazai, O. M. Abdulmunem, K. Y. Qader, S. S. Chiad, N. . Habubi, Investigation of some physical properties of Mn doped ZnS nano thin films”, AIP Conference Proceedings 2213 (1) (2020): 020101.

[35] E. S. Hassan, K. Y. Qader, E. H. Hadi, S. S. Chiad, N.F. Habubi, K.H. Abass, “Sensitivity of nanostructured mn-doped cobalt oxide films for gas sensor application”, Nano Biomedicine and Engineering 12(3) (2020): 205-213.

[36] M. D. Sakhil, Z. M. Shaban, K. S. Sharba, N. F. Habub, K. H. Abass, S. S. Chiad, A. S. Alkelaby, “Influence mgo dopant on structural and optical properties of nanostructured cuo thin films”, NeuroQuantology 18 (5) (2020): 56-61.

[37] M. S. Othman, K. A. Mishjil, H. G. Rashid, S. S. Chiad, N. F. Habubi, Al-Baidhany I. A., “Comparison of the structure, electronic, and optical behaviors of tin-doped CdO alloys and thin films”, Journal of Materials Science: Materials in Electronics 31(11) (2020): 9037-9043.

[38] S. S. Chiad, H. A. Noor, O. M. Abdulmunem, N. F. Habubi, M. Jadan, J. S. Addasi, “Optical and structural performance of nanostructured Te thin films by (CSP) with various thicknesses”, Journal of Ovonic Research 16 (1) (2020): 35-40.

[39] H. T. Salloom, E. H. Hadi, N. F. Habubi, S. S. Chiad, M. Jadan, J. S. Addasi, “Characterization of silver content upon properties of nanostructured nickel oxide thin films”, Digest Journal of Nanomaterials and Biostructures 15(4) (2020): 1189-1195.

[40] M. Irfan, A. Umar, A. Al-Hajry, “Synthesis, structural, and optical studies of manganese-doped zinc oxide thin films prepared by spray pyrolysis”, Journal of Nanoparticle Research 17(8) (2015): 337.

[41] M. A. Ahmed, M. M. El-Nahass, M. Bakr, “Synthesis and characterization of Mn-doped ZnO thin films using spray pyrolysis technique”, Materials Science in Semiconductor Processing 23 (2014): 25-33.

[42] K. M. Krishna, K. V. Koteswara Rao, D. H. Kim, “Optical and magnetic properties of Mn doped ZnO thin films deposited by spray pyrolysis technique”, Journal of Magnetism and Magnetic Materials 378 (2015): 8-14.

[43] A. Khan, R. Ullah, A. Rehman, I. Ul-Haq, “Influence of annealing temperature on structural and optical properties of Mn-doped ZnO thin films synthesized by chemical spray pyrolysis”, Materials Science in Semiconductor Processing 47 (2016): 108-114.

[44] F. A. Alzahrani, M. S. Al-Salhi, S. AlFaify, H. U. Khan, “Synthesis and characterization of Mn-doped ZnO thin films deposited by spray pyrolysis”, Journal of Materials Science: Materials in Electronics, 30(2) (2019): 1303-1309.

[45] A. Y. Oral, Z. B. Bah¸si, M. H. Aslan, "Microstructure and optical properties of nanocrystalline ZnO and ZnO:(Li or Al) thin films", Appl. Surf. Sci. 253 (2006): 4593–4598.

[46] H. A. Hussin, R. Al-Hasnawy, R. I. Jasim, N. F. Habubi, S. S. Chiad, "Optical and structural properties of nanostructured CuO thin films doped by Mn", Journal of Green Engineering 10(9) (2020): 7018-7028.

[47] S. S. Chiad, A. S. Alkelaby, K.S. Sharba, "Optical Conduct of Nanostructure Co_3O_4 rich Highly Doping Co_3O_4: Zn alloys", Journal of Global Pharma Technology 11(7) (2020): 662-665.

[48] N. Y. Ahmed, B. A. Bader, M. Y. Slewa, N. F. Habubi, S. S. Chiad, "Effect of boron on structural, optical characterization of nanostructured Fe_2O_3 thin films", NeuroQuantology 18 (6) (2020): 55-60.

[49] J. Qiu, B. Guo, H. Zhang, C. Yu, F. Li, "Insights into Working Mechanism of Alkali Metal Fluorides as Dopants of ZnO Films in Inverted Polymer Solar Cells", J. Phys. Chem. C 122 (2018): 24542–24549.

[50] R. S. Ali, H. S. Rasheed, N. D. Abdulameer, N. F. Habubi, S. S. Chiad, "Physical properties of Mg doped ZnS thin films via spray pyrolysis", Chalcogenide Lettersthis link is disabled, 20 (3) (2023): 187–196.

[51] A. A. Khadayeir, R. I. Jasim, S. H. Jumaah, N. F. Habubi, S. S. Chiad, "Influence of Substrate Temperature on Physical Properties of Nanostructured ZnS Thin Films", Journal of Physics: Conference Series1664 (1) (2020).

[52] R. S. Ali, N. A. H. Al Aaraji, E. H. Hadi, K. H Abass, N. F. Habubi, S. S Chiad, "Effect of Lithium on Structural and Optical Properties of anostructured CuS Thin", Journal of Nanostructuresthis link is disabled, 10(4) 2(020): 810–816.

[53] A. S. Al Rawas, M. Y. Slewa, B. A. Bader, N. F. Habubi, S.S. Chiad, "Physical characterization of nickel doped nanostructured TiO_2 thin films", Journal of Green Engineering10 (9) (2020): 7141-7153.

[54] H. Liu, F. Zeng, Y. Lin, G. Wang, F. Pan. "Correlation of oxygen vacancy variations to band gap changes in epitaxial ZnO thin films", Appl. Phys. Lett. 102 (2013): 181908.

[55] K. D.A. Kumar, S. Valanarasu, S. R. Rosario, V. Ganesh, M. Shkir, C. Sreelatha, S AlFaify, "Evaluation of the structural, optical and electrical properties of AZO thin films prepared by chemical bath deposition for optoelectronics", Solid State Sci. 78 (2018): 58–68.

[56] E. S. Hassan, T. H., Mubarak, S. S. Chiad, N. F. Habubi, A. A. Khadayeir, M. O. Dawood, I. A. Al-Baidhany, "Physical Properties of indium doped Cadmium sulfide thin films prepared by (SPT)", Journal of Physics: Conference Series 1294(2) (2019).

[57] S. S. Chiad, N. F. Habubi, W. H. Abass, M. H. Abdul-Allah, "Effect of thickness on the optical and dispersion parameters of $Cd_{0.4}Se_{0.6}$ thin films", Journal of Optoelectronics and Advanced Materials 18 (9-10) (2016): 822-826.

[58] M. O. Dawood, S. S. Chiad, A. J. Ghazai, N. F. Habubi, O. M. Abdulmunem, "Effect of Li doping on structure and optical properties of NiO nano thin-films by SPT", AIP Conference Proceedings 2213 (2020): 020102.

[59] C.-H. Liang, W.-S. Hwang, W.-L. Wang, "Effects of growth temperature and target material on the growth behavior and electroopticalproperties of ZnO:Al films deposited by high-rate steered cathodic arc plasma evaporation", Appl. Surf. Sci. 333 (2015) 1–12.

[60] L. Yang, X. Yan, "Preparation and characterization of manganese-doped ZnO thin films by sol-gel method", Journal of Materials Science: Materials in Electronics 30 (3) (2019): 2653-2659.

[61] A. A. Khadayeir, E. S. Hassan, S. S. Chiad, N. F. Habubi, K. H. Abass, M. H. Rahid, T. H Mubarak, M. O. Dawod, I.A. Al-Baidhany, "Structural and Optical Properties of Boron Doped Cadmium Oxide", Journal of Physics: Conference Series 1234 (1) (20119): 012014

[62] H. T. Salloom, R. I. Jasim, N. F. Habubi, S. S. Chiad, M. Jadan, J. S. Addasi, "Gas sensor using gold doped copper oxide nanostructured thin films as modified cladding fiber", Chinese Physics Bthis link is disabled 30(6) (2021):068505.

[63] K.Y. Qader, R. A. Ghazi, A. M. Jabbar, K. H. Abass, S. S. Chiad, "Reduce of energy gap of CuO nano structure film by Ag doping", Journal of Green Engineering 10(10) (2020):7387-7398.

[64] S. S. Ingole, S. M. Pawar, and P. V. Adhyapak, "Mn-doped ZnO thin films by spray pyrolysis", Journal of Materials Science: Materials in Electronics 29 (9) (2018): 7297-7305.

[65] S. S. Ingole, S. M. Pawar, and P. V. Adhyapak, "Effect of Mn doping on the structural and optical properties of ZnO thin films deposited by spray pyrolysis", Journal of Materials Science: Materials in Electronics 30 (2) (2019): 1744-1752.